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Development and Performance of the ACTS High Speed VSAT

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DEVELOPMENT AND PERFORMANCE OF THE ACTS HIGH SPEED VSAT

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I. Abstract

The Advanced Communication Technology Satellite (ACTS), developed by the U.S. National Aeronautics and Space Administration (NASA) has demonstrated the breakthrough technologies of Ka-band, spot beam antennas, and on-board processing. These technologies have enabled the development of very small aperture terminals (VSAT) and ultra-small aperture terminals (USAT) which have capabilities greater than were previously possible with conventional satellite technologies.

However, the ACTS baseband processor (BBP) is designed using a time division multiple access (TDMA) scheme, which requires each earth station using the BBP to transmit data at a burst rate which is much higher than the user throughput data rate. This tends to mitigate the advantage of the new technologies by requiring a larger earth station antenna and/or a higher-powered uplink amplifier than would be necessary for a continuous transmission at the user data rate. Conversely, the user data rate is much less than the rate that can be supported by the antenna size and amplifier.

For example, the ACTS T1 VSAT operates at a burst rate of 27.5 Mbps, but the maximum user data rate is 1.792 Mbps. The throughput efficiency is slightly more than 6.5%. For an operational network, this level of overhead will greatly increase the cost of the user earth stations, and that increased cost must be repeated thousands of times, which may ultimately reduce the market for such a system.

The ACTS High Speed VSAT (HS VSAT) is an effort to experimentally demonstrate the maximum user throughput data rate which can be achieved using the technologies developed and implemented on ACTS. Specifically, this was done by operating the system uplinks as frequency division multiple access (FDMA), essentially assigning all available TDMA time slots to a single user on each of two uplink frequencies. Preliminary results show that using a 1.2-m antenna in this mode, the HS VSAT can achieve between 22 and 24 Mbps out of the 27.5 Mbps burst rate, for a throughput efficiency of 80-88%.

This paper describes the modifications made to the T1 VSAT to enable it to operate at high speed, including hardware considerations, interface modifications, and software modifications. In addition, it describes the results of NASA HS VSAT experiments, continuing work on an improved user interface, and plans for future experiments.

II. Introduction / Background

The ACTS satellite has developed and demonstrated numerous new technologies, each of which contributes to smaller, less expensive, more capable earth stations than were possible with older technologies. In particular, the use of on-board processing, Ka-band frequencies, and spot beam antenna technologies on the spacecraft improve the link capabilities for the earth stations.

Spot beam antennas provide increased antenna gain for both uplink receive and downlink transmit antennas, when compared with older full-continent antenna contours. The use of Ka-band frequencies, at a wavelength half that of Ku-band, provides an additional 6 dB of antenna gain for equally sized antennas, or alternatively, allows the antenna size to be reduced while maintaining equal gain. The use of on-board processing, in addition to the advantages it provides in network flexibility, improves the link margin by up to 3 dB by demodulating and regenerating the signal on-board the satellite, thus decoupling uplink noise from downlink noise. [1,2]

In order to simplify the design of the ACTS baseband processor (BBP), the system was designed to share capacity in a time division multiple access (TDMA) mode. This relieved the satellite of the requirement to demodulate multiple carriers on-board, but it placed the burden on the earth stations of maintaining precise timing. It also resulted in a transmitted symbol rate many times the usable data rate. The ACTS T1 VSAT operates at a maximum user data rate of 1.792 Mbps, but the modulated burst rate is 27.5 Mbps. [1,2,3]

The design of the T1 VSAT connects each 64 Kbps channel from the RF link, where one channel corresponds to one TDMA time slot, to an individual port between the modem and an off-the-shelf digital switch, which is integrated into the VSAT. The highest capacity interface from the switch is a T1, multiplexing 24 channels at 64 Kbps each, for a maximum single-port data rate of 1.536 Mbps. [2,3]

The High Speed VSAT (HS VSAT) is the result of an effort to improve the throughput efficiency of the ACTS VSAT by eliminating, in experimental scenarios, any uplink TDMA and by devoting all the time slots in the frame to a single earth station. The design of the HS VSAT calls for the individual channels to be combined in a single high speed interface, rather than multiple 64 Kbps ports, and then buffered and formatted to meet standard network protocols and data rates. A HS VSAT outdoor unit is shown in Figure 1.

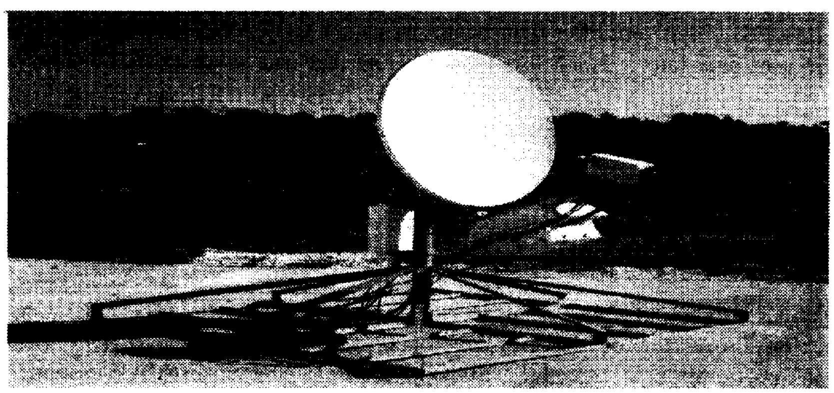

Figure 1 – HS VSAT Outdoor unit

III. Architecture

The changes needed to convert the T1 VSAT to the HS VSAT were limited to the modem, digital interface, and software. The RF chain of the T1 VSAT was designed to support a burst rate of 27.5 Mbps. This originally presented a problem since the high power frequency doubler (HPFD), a solid state component representing the last stage of the uplink chain, was originally designed for a maximum duty cycle of 33%. Later versions of the HPFD, however, could support a 100% duty cycle, and no modifications were required.

The required software changes were of two types: those associated with the digital switch, and those associated with port assignments in the modem. Since the T1 VSAT's digital switch was not appropriate for the HS VSAT interface, T1 VSAT software routines associated with mapping the user interfaces to the modem ports through this switch were discarded. This included most of the functionality of the Call Manager (CM) software, a separate software module which compiles together with the Modem Manager (MM) to make the executable T1 VSAT software.

The CM primarily handles control of the switch, converting essential sequences on an attached handset into ACTS orderwire requests. It also makes port assignments to ensure traffic is routed from the modem through the switch to the user interface. Without the switch, the remaining functions of the CM are principally orderwire-handling for call setups and teardowns, which can be handled in a minimal way with a much simpler software routine. The CM was consequently discarded and replaced with a minimum-function High-Speed Call Manager (HSCM).

The most significant software changes are in the routines that handle call setups and port assignments (i.e. reacting to orderwire messages from the Master Control Station). The HS VSAT software is required to recognize high-speed call setups and assign channels included in them to the high-speed port. This software was modified from the T1 VSAT software to allow multiple channels to be assigned to a single port address.
Development of the high-speed port involved the replication of the T1 VSAT circuit buffer cards, whose primary purpose is buffering data between the modem bus and the serial port connection. It also involved the definition of a high-speed port address in the address space, and implementation of the custom T1 VSAT address and data bus interfaces on the board. Initial sets of experiments were performed using a prototype high-speed interface, and an improved high-speed interface has been developed to support further experimentation.

The new HS VSAT interface board for the ACTS satellite will enable services in the 25 Mbps range, thus increasing user throughput's efficiency from 6.5% to over 80 %. To maximize the number of services provided and to accommodate the maximum number of users, the HS VSAT architecture consists of the high-speed board and a commercial Asynchronous Transfer Mode (ATM) concentrator. This off-the-shelf device, shown in Figure 2, allows several high data rate interfaces while also doing all the processing for ATM transmission. Figure 3 shows the end to end user interface between the ATM concentrator, the HS VSAT terminals and possible applications.

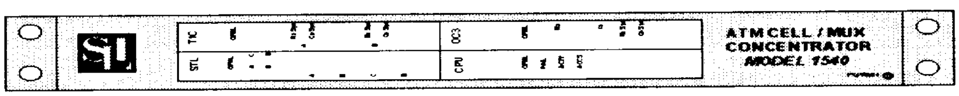

Figure 2 – ATM Cell Concentrator [4]

General Description [4]

The Cell Mux Concentrator (CMC) is a flexible, modular, scaleable and cost effective ATM cell Multiplexer (Mux), which operates utilizing ATM Cell Bus architecture. It provides the system/network integrator with an ATM Cell platform that operates on the "net edge" to concentrate both Cell traffic (Frame Relay and ATM) and Legacy (Non ATM) traffic. Some of the features include:

- Supports both ATM Cell and Legacy Data Applications and Networks
- Performs HEC byte search functions
- Multiplexes and Switches ATM Cell Traffic
- Synchronous Interfaces for Satellite and Secure Networks
- Cost effective access to ATM networks for Legacy communications equipment and applications

The cell traffic interface modules include:

1) OC3 - Single Port OC 3 SONET Facility Interface
The standard OC3 Module comes complete with a short haul, multimode SC type connector for connection to an ATM switch or for connection to a SONET OC-3 facility. The OC3 has a maximum data rate of 155 Mbps and is fully UNI 3.0 compliant.

2) DS3 - Single Port DS 3 Facility Interface
The DS-3 Module has BNC connectors for connection to either a DS-3 ATM switch or ATM facility. The DS3 has a maximum data rate of 45 Mbps and is fully UNI 3.0 compliant.

The Dual Port Serial Synchronous Interface (DSC) can transmit and receive up to 20 Mbps (in 8 Kbps increments) of synchronous, serial ATM cell traffic on each of its two ports. Once the serial data is transmitted to the HS VSAT, it is converted to a parallel byte (8 bits) using a Serial to Parallel Converter. The parallel data, along with the Unique Word, is multiplexed at twice the speed of the transmission rate to accommodate both serial ports.

Due to the ACTS TDMA system, "elastic" (expansion/compression) data storage is necessary to queue data and prevent losses during "dead time" in a bursty environment that could lead to system overflow and underflow.
Once data is multiplexed and stored in the transmitting FIFO, the user ID from the VSAT microprocessor is received and decoded. The transmitted data is sent to the ACTS VSAT Modulator where is re-formatted into multiples of 64 Kbps to be transmitted to the satellite.

On the receive side, the opposite operation occurs. The receive address is decoded and the Unique Word is detected; incoming data is stored into the receive FIFO. Once the data is available in the FIFO, it is re-formatted and demultiplexed to be transmitted to the appropriate DSC receiving port.

Most of the logic functions performed on the HS VSAT board were implemented in a single high-speed Field Programmable Gate Array (FPGA) chip. Address decoding, unique word detection, read and write control operations, empty and full flag monitoring, data conversion (S/P and P/S), multiplexing and demultiplexing are some examples of these functions that allow for a more flexible design using the FPGA chip.

By using the HS VSAT interface to the ATM programmable concentrator, any number of possible applications can be transmitted through ACTS. The ATM concentrator can be configured to process and format ATM cells from any of its interface modules and route them to the DSC Interface module. Figure 5 shows a block diagram of the end-to-end user interface.

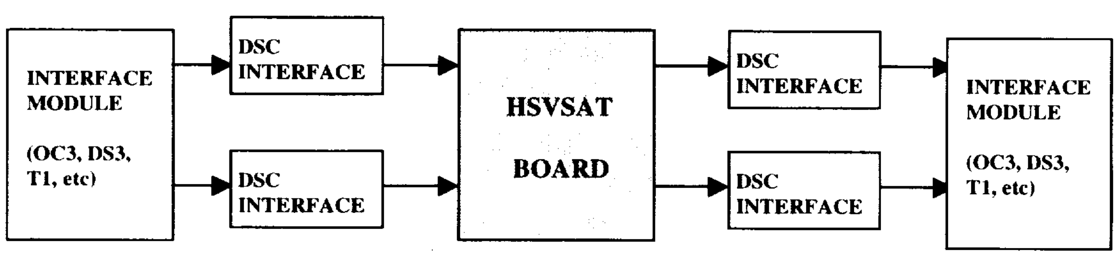

Figure 5 – HS VSAT User Interface Block Diagram

V. Results and Future Experiments

The HS VSAT conceptual design was tested and validated at NASA Lewis Research Center using a prototype HS VSAT board. Using commercial off-the-shelf Bit Error Rate Test Equipment (BERT), the HS VSAT throughput was verified up to 375 channels at 64-Kbps each for a total throughput of 24 Mbps. Although the ACTS HS VSAT maximum data rate is 27.6 Mbps or 432 channels, there is some overhead in the TDMA frame, thus allowing only a true user data rate up to 24 Mbps in 64 Kbps increments. Bit Error Rate (BER) measurements obtained were in the order of 10^{-10} or better for duplex connection between 1.2m antennas with a Signal to Noise (SNR) ratio of approximately 19 dBm. A picture of the ACTS VSAT ground terminal is shown in Figure 6.

After the succesful demonstration of the HS VSAT prototype board, a final version of the design was fabricated. By using PC boards for the final version, system reliability is improved by eliminating some of the thermal noise problems previously encountered with the prototype board. These boards are ready to be integrated with the ATM concentrator to start final validation of this system.

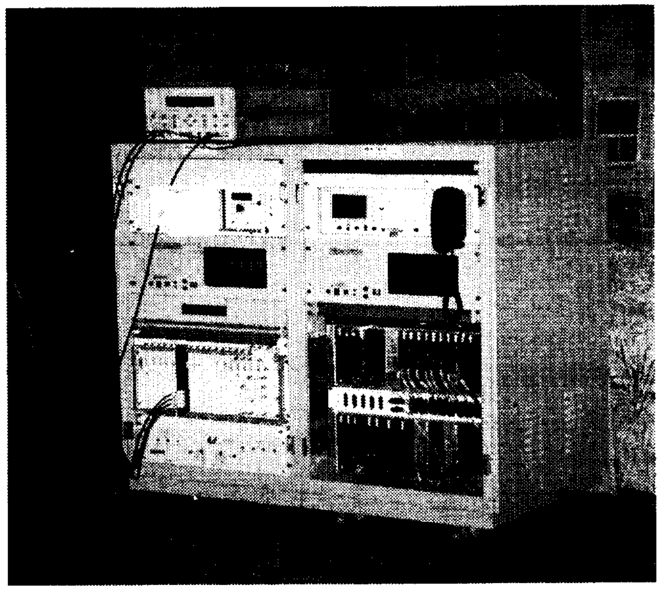

Figure 6 – ACTS VSAT ground terminal

Possible future experiments are being planned including:

- Telemedicine / Telemammography Demonstration
- ATM over satellite
- TCP/IP over satellite
- Videoconferencing / Distance Education
- LAN to ATM networks
- High Speed Internet Demonstration

VI . Conclusion

A flexible, scaleable HS VSAT interface for ACTS has been discussed in detail. This new interface will allow cost effective access to ATM networks and transmission of ATM cells at low speeds over commercial systems. The new system is expected to be fully operational by fall of 1998. New experiments can be scheduled through the ACTS experiments office.

VII. References

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